COMBINATION FLOW THROUGH INJECTION AND ISOLATION VALVE FOR HIGH PRESSURE FLUIDS

CROSS REFERENCE RELATED APPLICATION INFORMATION

This application claims priority from United States Provisional Patent Application No. 60/550,930, filed March 5, 2004. The contents of these applications are incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0001] The invention relates generally to the field of high pressure fluids and, more specifically, to a combination of multiple isolation valves that permit introduction of flow path without interruption of flow from the fluid source.

DESCRIPTION OF RELATED ART

[0002] Conventional 6-port face shear valves, also referred to as face seal valves, used in high pressure liquid chromatography (HPLC) provide ports that interface with the sample, the syringe, the pump, the column and the two ends of the sample loop. Such face seal valves must be rotated to switch from one port to another. The rotation of the face seal under high pressure inherently causes damage to the plastic mating surfaces because the fluid port openings must slide against the rotor surface causing fatigue of the rotor material. This results in shortened face seal valve life. In addition, it is necessary to temporarily block flow during the sample injection process and sample dispersion occurs.

[0003] At higher chromatography pressures, e.g., greater than 15,000 psig or 100 MPa, what is needed is a flow-through isolation sample injection valve that can provide high sample injection life with minimal sample distortion and minimal pump pressure pulsing.

BRIEF SUMMARY OF THE INVENTION

[0004] To address the above and other issues, the present invention describes a combination of multiple flow-through high pressure isolation valves for

high pressure fluids, and which is particularly suitable for use in HPLC applications as a substitute for the conventional face shear valve.

[0005] It is an object of this invention to provide a flow-through sample injection valve with fluid port openings that do not slide against a rotor surface causing fatigue of the rotor material.

[0006] It is another object of this invention to provide a flow-through sample injection valve which avoids flow of the sample through non-cylindrical passages so as to minimize sample dispersion.

[0007] In a particular aspect of the invention, the present invention is directed to a flow through injection valve, the flow through injection valve comprising:

a stationary member; a movable member, a surface of the stationary member interfacing with a surface of the movable member; and at least one pin isolation valve. The at least one pin isolation valve has a flow through internal conduit, and is movably disposed so that the internal conduit is capable of fluidically communicating with at least one flow through conduit in the movable member, and is movably disposed so that the internal conduit is capable of fluidically communicating with another flow through conduit in the movable member. The movable member of the flow through injection valve can further comprise first and second conduits for interfacing with internal conduits of first and second pin isolation valves, with the first and second conduits opening to a surface of the movable member; a third conduit enabling fluidic communication between the internal conduits of the first and second pin isolation valves; and a fourth conduit enabling fluidic communication between internal conduits of third and fourth pin isolation valves, the third pin isolation valve providing fluid flow, the fourth pin isolation valve exhausting the fluid flow. The movable member can move by rotation around an axis of rotation or by at least one of linear and curvilinear translation. One of the at least one pin isolation valves can be fluidically coupled to a sample loop of a high pressure liquid chromatography (HPLC) system. One of the at least one pin isolation valves can be in fluidic communication

with a pump supplying high pressure liquid to a high pressure liquid chromatography (HPLC) system. One of the at least one pin isolation valves can be fluidically coupled to a column discharging high pressure liquid from a high pressure liquid chromatography (HPLC) system.

[0008] In a specific aspect of the invention, the present invention is directed to a flow through injection valve, the flow through injection valve disposed around an axis of rotation, the injection valve comprising: at least two opposing valve ends disposed around the axis of rotation; the movable member comprising a rotor disposed between said valve ends, an axis of rotation of the rotor being one of parallel and coincident with the axis of rotation of the injection valve, and the rotor is disposed such that orientation of the rotor can change by rotation around the axis of rotation of the rotor. The rotor has an outer surface; at least two opposing surfaces each intersecting the outer surface; a first flow-through conduit having an opening on a first of the at least two opposing surfaces and an opening on a second of the at least two opposing surfaces; a second flow-through conduit having an opening on a first of the at least two opposing surfaces and an opening on a second of the at least two opposing surfaces; a flow through conduit having an opening on the outer surface and an opening on the first of the at least two opposing surfaces; and a flow through conduit having an opening on the outer surface and an opening on the second of the at least two opposing surfaces. The rotor further comprises a first sealing annulus for sealing the openings on the first of the at least two opposing surfaces; and a second sealing annulus for sealing the openings on the second of the at least two opposing surfaces.

[0009] The rotor further comprises a first pin isolation valve having an internal conduit, the first pin isolation valve disposed to move parallel to the axis of rotation of the injection valve, with the first pin isolation valve movably disposed so as to be capable of fluidically communicating, through said internal conduit, with the opening on the first flow-through channel on the first of the at least two opposing surfaces, and movably disposed so as to be capable of fluidically communicating, through the internal conduit, with the flow through conduit having an opening on the

outer surface and an opening on the second of the at least two opposing surfaces. The rotor further comprises a second pin isolation valve having an internal conduit, the second pin isolation valve disposed to move parallel to the axis of rotation of the injection valve, and movably disposed so as to be capable of fluidically communicating, through the internal conduit, with the opening on the first flow-through channel on the second of the at least two opposing surfaces, and movably disposed so as to be capable of fluidically communicating, through the internal conduit, with the flow through conduit having an opening on the outer surface and an opening on the second of the at least two opposing surfaces.

[0010] The rotor further comprises a third pin isolation valve having an internal conduit, the third pin isolation valve disposed to move parallel to the centerline of the injection valve, the third pin isolation valve movably disposed so as to be capable of fluidically communicating, through the internal conduit, with the opening on the second flow-through channel on the first of the at least two opposing surfaces, and movably disposed so as to be capable of fluidically communicating, through the internal conduit, with the flow through conduit having an opening on the outer surface and an opening on the second of the at least two opposing surfaces. The rotor further comprises a fourth pin isolation valve having an internal conduit, the fourth pin isolation valve disposed to move parallel to the centerline of the injection valve, the fourth pin isolation valve movably disposed so as to be capable of fluidically communicating, through the internal conduit, with the opening on the second flow-through channel on the second of the at least two opposing surfaces, and movably disposed so as to be capable of fluidically communicating, through the internal conduit, with the flow through conduit having an opening on the outer surface and an opening on the second of the at least two opposing surfaces.

[0011] The rotor can further comprise: a rotor clamp having an outer surface and an inner surface, the inner surface surrounding at least a portion of the outer surface of the rotor; a first opening on the outer surface of the rotor clamp penetrating the rotor clamp to coincide with the first opening on the outer surface of the rotor; and a second opening on the outer surface of the rotor clamp penetrating the

rotor clamp to coincide with the second opening on the outer surface of the rotor. The rotor clamp can further comprise drive means for driving the rotor to rotate around the axis of rotation of the rotor. The rotor clamp drive means can comprise a gear drive operator or a handle operator.

[0012] At least one of the valve ends can comprise: a stator enclosing the at least one pin isolation valve, the stator adjacent to the rotor; a sealing layer enclosed within the stator and enclosing the at least one pin isolation valve for sealing the at least one pin isolation valve; a Belleville spring washer; a Belleville spring; a load washer; and a spherical nut, the Belleville spring washer, the Belleville spring, the load washer and the spherical nut axially arranged to impose an axial force for sealing the sealing layer enclosing the pin isolation valve. Either of the first and second pin isolation valves can be fluidically coupled to a sample loop of a high pressure liquid chromatography (HPLC) system. Either of the third and fourth pin isolation valves can be in fluidic communication with a pump supplying high pressure liquid to a high pressure liquid chromatography (HPLC) system or in fluidic communication with a column discharging high pressure liquid to a high pressure liquid chromatography (HPLC) system.

[0013] In another embodiment, the present invention is directed to a multiple valve comprised of: a housing; a rotary flow through isolation valve disposed within the housing, with the isolation valve oriented in an axial direction for isolation of fluid flow, the isolation valve disposed around an axis of rotation, the isolation valve comprising: at least two opposing valve ends disposed around the axis of rotation; a rotor disposed between the valve ends, an axis of rotation of the rotor being substantially parallel and coincident with the axis of rotation of the isolation valve, with the rotor disposed such that orientation of the rotor can change by rotation around the axis of rotation of the rotor. The rotor has: an outer surface, at least two opposing surfaces each intersecting the outer surface; a flow-through conduit having an opening on a first of the at least two opposing surfaces and an opening on a second of the at least two opposing surfaces; a flow through conduit having an opening on the outer surface and an opening on the first of the at least two opposing surfaces; a

flow through conduit having an opening on the outer surface and an opening on the second of the at least two opposing surfaces; at least one blank opening on the first of the at least two opposing surfaces; and at least one blank opening on the second of the at least two opposing surfaces. The rotor further comprises: a first sealing annulus for sealing the openings on the first of the at least two opposing surfaces, and a second sealing annulus for sealing the openings on the second of the at least two opposing surfaces. The rotor further comprises: a first pin isolation valve, the first pin isolation valve disposed to move along the axis of rotation of the isolation valve, the first pin isolation valve movably disposed so as to be capable of fluidically communicating with the at least one blank opening on the first of the at least two opposing surfaces, and movably disposed so as to be capable of fluidically communicating with the flow through conduit having an opening on the outer surface and an opening on a second of the at least two opposing surfaces; and a second pin isolation valve, the second pin isolation valve disposed to move along the centerline of the isolation valve, the second pin isolation valve movably disposed so as to be capable of fluidically communicating with the at least one blank opening on the second of the at least two opposing surfaces, the second pin isolation valve movably disposed so as to be capable of fluidically communicating with the flow through conduit having an opening on the outer surface and an opening on the second of the at least two opposing surfaces. The multiple valve further comprises: a linear flow through injection valve, the injection valve comprising: a stationary member; a movable member, the stationary member and the movable member interfacing at a surface, the movable member disposed to slide along the surface; a chamber disposed between the stationary member and the movable member, the chamber bounded by the surface; the movable member having a first flow through conduit having a first opening interfacing with the chamber and a second opening on a surface of the movable member not interfacing with the chamber, the movable member having a second flow through conduit having a first opening interfacing with the chamber and a second opening on a surface of the movable member not interfacing with the chamber. The movable member further comprises: a third flow through conduit having a first opening and a second opening each on a surface of the movable member interfacing with the chamber; and a fourth flow through conduit having a first opening

and a second opening each on a surface of the movable member interfacing with the chamber.

[0014] In yet another embodiment, the present invention is directed to a multiple valve comprised of: a housing; a linear flow through isolation valve disposed within the housing, the isolation valve comprising: a stationary member; a movable member, the stationary member and the movable member interfacing at a surface, the movable member disposed to slide along the surface; a chamber disposed between the stationary member and the movable member, with the chamber bounded by the surface. The movable member has a first flow through conduit having an opening interfacing with the chamber and an opening on a surface of the movable member not interfacing with the chamber, a second flow through conduit having an opening interfacing with the chamber, and an opening on a surface of the movable member not interfacing with the chamber, a first blank opening on the surface bounding the chamber, and a second blank opening on the surface bounding the chamber. The multiple valve further comprises a linear flow through injection valve, the injection valve comprising: a stationary member; a movable member, the stationary member and the movable member interfacing at a surface, the movable member disposed to slide along the surface; and a chamber disposed between the stationary member and the movable member, the chamber bounded by the surface. The movable member has: a first flow through conduit having a first opening interfacing with the chamber and a second opening on a surface of the movable member not interfacing with the chamber, a second flow through conduit having a first opening interfacing with the chamber and a second opening on a surface of the movable member not interfacing with the chamber, a third flow through conduit having a first opening and a second opening each on a surface of the movable member interfacing with the chamber, and a fourth flow through conduit having a first opening and a second opening each on a surface of the movable member interfacing with the chamber,.

[0015] The linear flow through injection valve of the multiple valve can further comprise: at least one of a (a) first pin isolation valve, (b) second pin isolation

valve, (c) third pin isolation valve, and (d) fourth pin isolation valve; the first pin isolation valve having an internal conduit, the first pin isolation valve disposed within an opening within the stationary member interfacing with the chamber so that the internal conduit of the first pin isolation valve is movably disposed to be in fluidic communication with the first opening on a first flow through conduit of the movable member, and movably disposed to be in fluidic communication with the first opening of the third flow through conduit, the second pin isolation valve having an internal conduit, the second pin isolation valve disposed within an opening within the stationary member interfacing with the chamber so that the internal conduit of the second pin isolation valve is movably disposed to be in fluidic communication with the first opening on a second flow through conduit of the movable member, and movably disposed to be in fluidic communication with the second opening of the third flow through conduit, the third pin isolation valve having an internal conduit, the third pin isolation valve disposed within an opening within the stationary member interfacing with the chamber so that the internal conduit of the third pin isolation valve is movably disposed to be in fluidic communication with the first opening of the fourth flow through conduit, and movably disposed to be in fluidic communication with the first opening of the first flow through conduit. The fourth pin isolation valve has an internal conduit, the fourth pin isolation valve disposed within an opening within the stationary member interfacing with the chamber so that the internal conduit of the fourth pin isolation valve is movably disposed to be in fluidic communication with the second opening of the fourth flow through conduit, and movably disposed to be in fluidic communication with the first opening of the second flow through conduit.

[0016] Those skilled in the art recognize that any combination such as rotary isolation and linear injection, linear isolation and rotary injection, rotary injection and rotary isolation, and linear injection and linear isolation multiple valves can be constructed. Furthermore, any of the rotary injection, rotary isolation, linear injection, and linear isolation valves can be constructed independently.

[0017] The present invention is also directed to a method of operating a flow through injection valve, the valve comprising: a movable member, the movable member having first and second conduits for interfacing with internal conduits of first and second pin isolation valves, the first and second conduits opening to a surface of the movable member; a third conduit enabling fluidic communication between the internal conduits of the first and second pin isolation valves; a fourth conduit enabling fluidic communication between internal conduits of third and fourth pin isolation valves, the third pin isolation valve providing fluid flow, the fourth pin isolation valve exhausting the fluid flow;

(A) wherein the valve is in an initial position of flow isolation such that the third pin isolation valve providing fluid flow is in fluidic communication with the fourth pin isolation valve exhausting the fluid flow, the first pin isolation valve is in fluidic communication with the first conduit, and the second pin isolation valve is in fluidic communication with the second conduit; the method comprises the steps of: (I) wherein the first pin isolation valve interfaces with the first conduit, (1) moving the first pin isolation valve away from the first conduit; (2) moving the movable member, (3) moving the first pin isolation valve towards the movable member such that the internal conduit within the first pin isolation valve interfaces with the third conduit; and (II) wherein the second pin isolation valve interfaces with the second conduit, (1) moving the second pin isolation valve away from the second conduit; (2) moving the movable member, (3) moving the second pin isolation valve towards the movable member such that the internal conduit within the second pin isolation valve interfaces with the third conduit, thereby establishing fluidic communication between the first and second pin isolation valves; and

(III) wherein the third pin isolation valve interfaces with the fourth conduit, (1) moving the third pin isolation valve away from the fourth conduit; (2) moving the movable member; (3) moving the third pin isolation valve towards the first conduit to establish fluidic communication with the internal conduit of the third pin isolation valve; and (IV) wherein the fourth pin isolation valve interfaces with the fourth conduit, (1) moving the fourth pin isolation valve away from the fourth conduit; (2) moving the movable member; (3) moving the fourth pin isolation valve towards the second conduit to establish fluidic communication with the internal conduit of the

fourth pin isolation valve; and (B) wherein the valve is in an initial position of flow throughput such that at least one of (a) the third pin isolation valve providing fluid flow interfaces with the first conduit and (b) the fourth pin isolation valve exhausting the fluid flow interfaces with the second conduit, the method comprises the steps of: (III) wherein the third pin isolation valve interfaces with the first conduit, (1) moving the third pin isolation valve away from the first conduit, (2) moving the movable member, and (3) moving the third pin isolation valve towards the movable member such that the internal conduit within the third pin isolation valve interfaces with the fourth conduit; and (IV) wherein the fourth pin isolation valve interfaces with the second conduit, (1) moving the fourth pin isolation valve away from the second conduit, (2) moving the movable member, and (3) moving the fourth pin isolation valve towards the movable member such that the internal conduit within the second pin isolation valve interfaces with the first conduit; and (V) wherein the first pin isolation valve interfaces with the third conduit, (1) moving the first pin isolation valve away from said third conduit, (2) moving the movable member, and (3) moving the first pin isolation valve towards the movable member such that the internal conduit within the first pin isolation valve interfaces with the first conduit; and (VI) wherein the second pin isolation valve interfaces with the third conduit, (1) moving the second pin isolation valve away from the third conduit, (2) moving the movable member, and (3) moving the second pin isolation valve towards the movable member such that the internal conduit within the second pin isolation valve interfaces with the second conduit.

[0018] In another embodiment of the present invention, the present invention is directed also to a method of operating a multiple valve, the multiple valve comprising a flow through isolation valve, the flow through isolation valve comprising: a movable member, the movable member having first and second conduits for interfacing with internal conduits of first and second pin isolation valves, the conduits opening to a surface of the movable member; first and second blank openings for interfacing with the internal conduits of the first and second pin isolation valves, (A) wherein the valve is in an initial position of flow isolation such that at least one of (a) the first pin isolation valve providing fluid flow interfaces with the

first blank opening and (b) the second pin isolation valve exhausting the fluid flow interfaces with the second blank opening,

the method comprises the steps of: (I) wherein the first pin isolation valve interfaces with the first blank opening, (1) moving the first pin isolation valve away from the first blank opening, (2) moving the movable member, and (3) moving the first pin isolation valve towards the movable member such that the internal conduit within the first pin isolation valve interfaces with the first conduit opening to a surface of the movable member; and (II) wherein the second pin isolation valve interfaces with the second blank opening, (1) moving the second pin isolation valve away from the second blank opening,

(2) moving the movable member, and (3) moving the second pin isolation valve towards the movable member such that the internal conduit within the second pin isolation valve interfaces with the second conduit opening to a surface of the movable member, and (B) wherein the valve is in an initial position of flow throughput such that at least one of (a) the first pin isolation valve providing fluid flow interfaces with the first conduit and (b) the second pin isolation valve exhausting the fluid flow interfaces with the second conduit, the method comprises the steps of: (III) wherein the first pin isolation valve interfaces with the first conduit, (1) moving the first pin isolation valve away from the first conduit, (2) moving said movable member, and (3) moving the first pin isolation valve towards the movable member such that the internal conduit within the first pin isolation valve interfaces with the first blank opening; and (IV) wherein the second pin isolation valve interfaces with the second conduit, (1) moving the second pin isolation valve away from the second conduit, (2) moving the movable member, and (3) moving the second pin isolation valve towards the movable member such that the internal conduit within the second pin isolation valve interfaces with the second blank opening.

[0019] In the method of operating a flow through injection valve, the first and second conduits opening to a surface of the movable member can be in fluidic communication with a sample loop of a high pressure liquid chromatography (HPLC) system, or the first and second pin isolation valves can be in fluidic communication with a needle and a syringe of a high pressure liquid chromatography (HPLC) system,

or the third and fourth pin isolation valves can be in fluidic communication with a pump and a column of a high pressure liquid chromatography (HPLC) system,

[0020] In the method of operating a multiple valve, the multiple valve also comprises a flow through injection valve, the flow through injection valve comprising: a movable member, the movable member having first and second conduits for interfacing with internal conduits of first and second pin isolation valves, the first and second conduits opening to a surface of the movable member; a third conduit enabling fluidic communication between the internal conduits of the first and second pin isolation valves; a fourth conduit enabling fluidic communication between internal conduits of third and fourth pin isolation valves, the third pin isolation valve providing fluid flow, the fourth pin isolation valve exhausting the fluid flow; (A) wherein the valve is in an initial position of flow isolation such that the third pin isolation valve providing fluid flow is in fluidic communication with the fourth pin isolation valve exhausting the fluid flow, the first pin isolation valve is in fluidic communication with the first conduit, and the second pin isolation valve is in fluidic communication with the second conduit; the method comprises the steps of: (I) wherein the first pin isolation valve interfaces with the first conduit, (1) moving the first pin isolation valve away from the first conduit; (2) moving the movable member, (3) moving the first pin isolation valve towards the movable member such that the internal conduit within the first pin isolation valve interfaces with the third conduit; and (II) wherein the second pin isolation valve interfaces with the second conduit, (1) moving the second pin isolation valve away from the second conduit; (2) moving the movable member, (3) moving the second pin isolation valve towards the movable member such that the internal conduit with the second pin isolation valve interfaces with the third conduit, thereby establishing fluidic communication between the first and second pin isolation valves; and (III) wherein the third pin isolation valve interfaces with said fourth conduit, (1) moving the third pin isolation valve away from the fourth conduit; (2) moving the movable member; (3) moving the third pin isolation valve towards the first conduit to establish fluidic communication with the internal conduit of the third pin isolation valve ; and

(IV) wherein said fourth pin isolation valve interfaces with the fourth conduit, (1) moving the fourth pin isolation valve away from the fourth conduit; (2) moving the movable member; (3) moving the fourth pin isolation valve towards the second conduit to establish fluidic communication with the internal conduit of the fourth pin isolation valve.

[0021] The method of operating a multiple valve also comprises the steps of: (B) wherein the valve is in an initial position of flow throughput such that at least one of (a) the third pin isolation valve providing fluid flow interfaces with the first conduit and (b) the fourth pin isolation valve exhausting the fluid flow interfaces with the second conduit, the method comprises the steps of: (III) wherein the third pin isolation valve interfaces with the first conduit, (1) moving the third pin isolation valve away from the first conduit, (2) moving the movable member, and (3) moving the third pin isolation valve towards the movable member such that the internal conduit within the third pin isolation valve interfaces with the fourth conduit; and (IV) wherein the fourth pin isolation valve interfaces with the second conduit, (1) moving the fourth pin isolation valve away from the second conduit, (2) moving the movable member, and (3) moving the fourth pin isolation valve towards the movable member such that the internal conduit within the second pin isolation valve interfaces with the first conduit; and (V) wherein the first pin isolation valve interfaces with the third conduit, (1) moving the first pin isolation valve away from the third conduit, (2) moving the movable member, and (3) moving the first pin isolation valve towards the movable member such that the internal conduit within the first pin isolation valve interfaces with the first conduit; and (VI) wherein the second pin isolation valve interfaces with the third conduit, (1) moving the second pin isolation valve away from the third conduit, (2) moving the movable member, and (3) moving the second pin isolation valve towards the movable member such that the internal conduit within the second pin isolation valve interfaces with the second conduit.

[0022] In the method of operating a multiple valve, the first and second conduits opening to a surface of the movable member of the flow through injection valve can be in fluidic communication with a sample loop of a high pressure liquid

chromatography (HPLC) system, or the first and second pin isolation valves of the flow through injection valve are in fluidic communication with a needle and a syringe of a high pressure liquid chromatography (HPLC) system, or the third and fourth pin isolation valves of the flow through injection valve can be in fluidic communication with a pump and a column of a high pressure liquid chromatography (HPLC) system,

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] These and other features, benefits and advantages of the present invention will become apparent by reference to the following text and figures, with like reference numbers referring to like structures across the views, wherein:

[0024] FIG. **1A** illustrates a combination of multiple rotary flow-through isolation valves of the present invention in a side elevation cross-sectional view in the load position interfacing with a sample loop.

[0025] FIG. **1B** illustrates the combination of multiple flow-through rotary isolation valves of the present invention of FIG. **1A** in a transition position interfacing with a sample loop.

[0026] FIG. **1C** illustrates the combination of multiple flow-through rotary isolation valves of the present invention of FIG. **1A** in an injection position interfacing with a sample loop.

[0027] FIG. **2A** is a partial cut-away perspective view of the isolation portion of the combination of the multiple flow-through rotary isolation valves of FIGS. **1A-1C.**

[0028] FIG. **2B** is a perspective exploded view of the rotor of the isolation portion of the multiple flow-through rotary isolation valve of FIGS. **1A-1C**.

[0029] FIG. **3A** is a plan view of the housing of the multiple rotary flow-through isolation valves of FIGS. **1A-1C**.

[0030] FIG. **3B** is an elevation view of the housing of the multiple flow-through rotary isolation valves of FIGS. **1A-1C**.

[0031] FIG. **3C** is a detail view of a portion of the rotary isolation valve assembly of FIG. **3A.**

[0032] FIG. **4A** is a separated elevation section view at break lines **4B** of another embodiment of the present invention as a multiple valve comprised of a linear isolation valve and a linear injection valve.

[0033] FIG. **4B** is a separated elevation view at break lines **4A** of the embodiment of FIG. **4B.**

DETAILED DESCRIPTION OF THE INVENTION

[0034] This application incorporates by reference concurrently filed co-pending provisional application Serial No. (Attorney Docket No. WAA-358)

[0035] The present invention describes a combination isolation valve of multiple flow-through high pressure isolation valves for high pressure fluids. The combination isolation valve can replace the conventional face shear valve used in HPLC systems. The rotors are designed for use in high pressure fluid systems to permit switching to another flow path without temporarily blocking flow as would occur in face-shear valves as are customarily used in high pressure fluid systems, in particular in high pressure liquid chromatography . The sample fluid injection circuit may be isolated from the remainder of the HPLC system. Each of the combination multiple flow-through isolation valves include a housing having a bore there through and a cylindrical rotor rotatable within the bore.

[0036] When the isolate rotor is in its fluid flow position during the injection phase, fluid flows from a pump, through the isolation valve, to the sample injector circuit, back through another portion of the valve, and then to a column. By turning the rotor 90°, the fluid stop ports prevent the flow of fluid and isolate the sample circuit from the remainder of the HPLC system.

[0037] In particular, in FIG. **1A**, an inject rotor **11** of an injection valve **300** of combination or multiple isolation valve **10** is shown in a load phase in fluidic communication with a needle **12** to a valve pin **1** at a port **14** on a side of rotor **11.** The combination or multiple isolation valve **10** is comprised of an isolation valve **200**

and the injection valve **300.** Sample fluid flows from the pin **1** into internal conduit **16.** The sample fluid flows through typically a substantially 90° bend **15** to a port **18** on the outer surface of the rotor **11.** The port **18** is preferably fluidically coupled to an inlet flexible tube **20** and correspondingly to the sample loop **22** so that the sample fluid flows into the sample loop **22** and flows out through an outlet flexible tube **24.**

[0038] The outlet flexible tube **24** is preferably fluidically coupled to a port **26** that is on the outer surface of rotor **11** through a valve pin **2** and in turn to an internal conduit **28.** The sample fluid flows through typically a substantially 90° bend **29** to a port **30** on an opposite side of the rotor **11.** A syringe **32** can be fluidically coupled to the port **30** so as to provide negative pressure in the flexible tube **24,** sample loop **22,** flexible tube **20** and needle **12** for drawing up the sample fluid and to permit the sample fluid to be aspirated into the sample loop **22.**

[0039] The inject rotor **11** includes ports **40** and **42** which interface through internal channel **44;** and ports **46** and **48** which interface through internal channel **50.** An annular space **52** is formed on one side of the rotor **11** providing fluidic communication between ports **14, 40** and **46.** An annular space **54** is formed on the opposite side of the rotor **11** providing fluidic communication between ports **30, 42** and **48.**

[0040] During the load phase, the inject rotor **11** is isolated from the high pressure pump **101** and column **102** by means of an isolation rotor **61.** The two rotors **11** and **61** interface through high pressure tubing **36** and **38.** In particular, high pressure tubing **36** is fluidically coupled with internal channel **50** through valve pin **3** at port **46** while high pressure tubing **38** is fluidically coupled to internal channel **50** through valve pin **4.** The high pressure tubing **36** is fluidically coupled to isolate rotor **61** through valve pin **5** which interfaces with the rotor **61** at blank port **82.** Correspondingly, the high pressure tubing **38** is fluidically coupled to isolation rotor **61** through valve pin **6** which interfaces with the rotor **61** at blank port **84.** Therefore, during the load phase, the pressure within the high pressure tubing **36** and **38** is substantially atmospheric, i.e., 0 psig or 0.101 MPa absolute.

[0041] The isolation rotor **61** includes ports **62** and **64** which interface through internal channel **66.** High pressure pump **101** is fluidically coupled to port **70** by means of internal channel **74.** The pump **101** interfaces with the outer surface of rotor **61** at a port **78.** Similarly, column **102** is fluidically coupled to port **72** by means of internal channel **76.** The column **102** interfaces with the outer surface of rotor **61** at a port **80.**

[0042] The inject rotor **11** can include a wash pump interfacing at port **40** and a wash discharge interfacing at port **42.** Since stagnant flow can occur in the internal rotor passageway **44**, rotor wash supply connection **110** **is** provided to connect from a separate wash pump (not shown) while wash discharge connection **112** enables discharge of the used wash solution.

[0043] The wash pump washes the internal chamber **44** following sample injection. An annular space **88** is formed on one side of the rotor **61** providing fluidic communication between ports **62** and **70.** An annular space **90** is formed on the opposite side of the rotor **61** providing fluidic communication between ports **64** and **72.**

[0044] FIG. **1B** illustrates the transition phase between loading of the sample into the sample loop **22** and the injection phase where the sample within the loop **22** is injected by high pressure pump **101.** During the transition phase, the isolation rotor **61** remains in the same position as during the load phase. Only orientation of the inject rotor **11** is changed. Specifically, the rotor **11** is rotated so that the valve pins **1** and **2** are disconnected from the sample loop **22,** thereby isolating the needle **12** and the syringe tube **32** from the sample loop **22.** The valve pin **1** is inserted into port **40** while the valve pin **2** is inserted into port **42** so that the needle and syringe are fluidically coupled to each other through internal conduit **44.**

[0045] FIG. **1C** illustrates the injection phase when high pressure liquid is supplied from the pump **101** to sample loop **22** and on to the column **102.**

Specifically, in the injection phase, the rotor **11** remains in the position achieved during the transition phase. The rotor **61** is rotated so that the valve pins **5** and **6** are disconnected from the blank ports **82** and **84,** respectively. The valve pin **5** is now connected to port **70** so as to cause fluidic communication between the pump **101** and the high pressure tubing **36.** Correspondingly, the valve pin **6** is now connected to port **72** so as to cause fluidic communication between the high pressure tubing **38** and the column **102.**

[0046] The annular spaces **88** and **90** formed on opposite sides of the rotor **61** provide a high pressure seal annulus for the rotor **61.**

[0047] Those skilled in the art recognize that following the inject phase illustrated in FIG. **1C,** the flow through isolation valve **200** and the flow through injection valve **300** can be returned to the load phase by reversing the operation back to the transition phase illustrated in FIG. **1B** and subsequently to the load phase illustrated in FIG. **1A.**

[0048] FIG. **2A** illustrates a perspective view of the isolation rotor **61** as it is disposed within a valve body to form a valve assembly **200.** The components of valve assembly **200** typically are centered around an axis of rotation such as centerline **200CL.** Specifically, the rotor **61** is positioned so that stators **202** and **204** are disposed on either end of the rotor **61.** Belleville springs **220** and **222** deflect the axial loads along the centerline **200CL** which act on the rotor **61.** The Belleville springs **220** and **222** and Belleville washers **232** and **234** are mounted on an end of both stators **202** and **204** by means of flanges **224** and **226.** The load washers **224** and **226** are locked into position by spherical nuts **228** and **230.** Both sets of sealing layers **206** and **208** are compressed by the axial forces imposed by Belleville spring washers **232** and **234,** respectively. The rotor **61** is comprised preferably of PEEK (polyetheretherketone) or PEEK blend. The rotor clamp **240** and the stators **202** and **204** are comprised preferably of Type 316 stainless steel

[0049] The foregoing materials are not exclusive and other materials can be applied by those skilled in the art.

[0050] The rotor **61** is shown in a cutaway view disposed between stators **202** and **204.** The rotor **61** is sealed by a set of three sealing layers **206** and **208** set around the valve pins **5** and **6,** respectively. The preferred materials for the sealing layers **206** and **208** comprise PEEK, PTFE (polytetrafluorethylene), PEEK in that order.

[0051] The foregoing materials are not exclusive and other materials can be applied by those skilled in the art.

[0052] The respective ends **242** and **244** of the flow through isolation valve **200** can be considered to comprise the stators **202** and **204,** the sealing layers **206** and **208,** Belleville spring washers **232** and **234**, Belleville springs **220** and **222**, load washers **224** and **226** and spherical nuts **228** and **230**.

[0053] FIG. **2B** is an exploded view of a portion of the components comprising a first variation of the embodiment of the flow through isolation valve **200.** Pump supply fitting **101** interfaces with port **78** in the rotor **61** and outlet supply to column fitting **102** interfaces with port **80** in the rotor **61.** Face seal valve supply pin **6** is surrounded by stator **204** and interfaces with one end of rotor **61** while face seal valve discharge pin **5** is surrounded by stator **202** and interfaces with the opposite end of rotor **61.** During normal operation, only the pins **5** and **6** which are surrounded by the stators **202** and **204** are moved either away from or back towards the rotor **61.** The pump supply fitting **101** and outlet supply to column fitting **102** are maintained normally in position except that they are rotated together with the rotation of the rotor **61.** The rotor **61** and rotor clamp **94** are rotated around the centerline **200CL** by means of drive gear **205.**

[0054] When the rotor **61** is in its fluid flow position, fluid flows from a separate high pressure pump, through the isolation valve **200**, to the sample injector circuit of injection valve **10**, back to the isolation valve **200**, and then to a column.

[0055] When the rotor **61** is rotated around axis of rotation centerline **200CL** by means of drive gear **205** through an angle of preferably 90°, the pins **5** and **6** are repositioned to the blank fluid flow stop ports **82** and **84** which prevent the flow of fluid and isolate the sample circuit of injection valve **10** from the remainder of the HPLC system. Those skilled in the art recognize that the drive gear **205** can be either a separate unit from the rotor clamp **94** or else the drive gear **205** can be an integral unitary structure combined with the rotor clamp **94** and even the rotor **61.** In addition, although shown as a drive gear, other means known to those skilled in the art such as, for example, an operating handle can be employed.

[0056] Although the ports **78** and **80** are preferably offset by an angle of about 90° from each other on the outer surface of the rotor, the ports can be aligned to be adjacent to each other. The offset is preferred due to the advantage of threaded connections for sealing and the resultant need for larger diameter tap holes. The threaded tap holes are generally 7.9 mm (5/16 in.) in diameter.

[0057] FIG. **3A** is a plan view of the housing **310** of the multiple flow-through isolation valves of FIGS. **1A-1C**. FIG. **3B** is an elevation view of the housing of the multiple flow-through isolation valves of FIGS. **1A-1C**.

[0058] The isolation valve assembly **200** is disposed within the housing **310.** The injection rotor **11** is disposed within injection valve assembly **300** around an axis of rotation such as centerline **300CL.** The isolation valve assembly **200** and the injection valve assembly **300** are disposed within the housing **310** through the end plates **312** and **314** preferably such that the axis of rotation centerlines **200CL** and **300CL** are parallel to each other. The valve assemblies **200** and **300** are operated by means such as a cam mechanism **320** known to those skilled in the art.

[0059] FIG. **3C** is a detail view of a portion of the isolation valve assembly of FIG. **3A**. As before, the rotor **61** is positioned so that stators **202** and **204** are disposed on either end of the rotor **61.** Belleville springs **220** and **222** deflect the axial loads along the centerline **200CL** which act on the rotor **61.** The Belleville spring **220** is mounted on an end of stator **202** by means of load washer **224.** The load washer **224** is locked into position by spherical nut **228.** Sealing layer set **206** is compressed by the axial force imposed by Belleville spring washer **232.** The spherical nuts **228** and **230** (not shown) are supported by, and penetrate through, housing end plates **312** and **314,** respectively.

[0060] As described previously with respect to FIG. **2A,** the rotor **61** is shown in a cutaway view in FIG. **3C** disposed between stators **202** and **204.** The rotor **61** is sealed by a set of three sealing layers **206** and **208** set around the pin valves **5** and **6,** respectively. As previously noted, the preferred materials and arrangement for the sealing layers comprise PEEK, PTFE, PEEK in that order. A valve end **240** of the flow through isolation valve assembly **200** can be considered to comprise the stator **202,** the sealing layer **206,** Belleville spring washer **232,** Belleville spring **220,** load washer **224,** and spherical nut **228.** Those skilled in the art recognize that the opposite valve end of the isolation valve assembly **200** is typically symmetrical and therefore is comprised typically of the corresponding symmetrical components.

[0061] In addition, those skilled in the art recognize that the isolation valve **200** and injection valve **300** of combination isolation valve **10** can also be configured by either of the alternate embodiments in any combination of embodiments described in co-pending US Provisional Patent Application No. (Docket No. WAA-358), previously disclosed as being incorporated by reference. That is, either the first and second embodiments, or the first and third embodiments, or the second and third embodiments, or only the second embodiment or only the third embodiment can be applied correspondingly as isolation valve **200** and injection valve **300.**

[0062] In a second embodiment, FIGS. **4A** and **4B** illustrate a combination linear flow through isolation valve **800** and linear flow through injection valve **850** each of which has a configuration similar to the generally cylindrically shaped second embodiment of rotor **61** illustrated in FIGS. **2A** and **2B.** The linear flow through isolation valve **800** is comprised of a stationary member **802** and a movable member **804.** The movable member **804** is similar to the rotor **202** except that instead of moving in a rotary motion, the movable member **804** moves by sliding linearly through the stationary member **802**. The movable member **804** can have any other type of cross-section such as, for example but not limited to, an oval shape or a square with smooth rounded corners. The rotary member **804** is made preferably of either a metal or a polymer or sapphire.

[0063] The stationary member **802** is comprised of two surfaces **806a** and **806b** which surround the movable slider member **804.** The two surfaces **806a** and **806b** each include self-energized lip seals **808a** and **808b**. The stationary member **802** also forms an interfacing surface **810** surrounding the movable member

[0064] Tube fitting **7** from the high pressure pump **101** is inserted into port **352** of the movable member **804** where it is sealed in a manner as to substantially prevent external leakage. Flow is provided from the high pressure pump **101** to the pin fitting **7** by means of flexible conduit **316** and coupling **312.** The internal conduit **38** within the fitting **7** is in fluidic communication with internal conduit **840** within the movable member **804** and with an open port **860** on the interfacing surface **810.** The open port **860** is in fluidic communication with a chamber or volume of space **812** within the stationary member **802** that is bordered by the interfacing surface **810.** The volume of space **812** within the stationary member **802** and the movable member **804** are sealed by the self-energized lip seals **808a** and **808b.** Isolation valve pin **5** penetrates through stationary member **802** at penetration **822** such that the valve pin **5** can move linearly up and down.

[0065] By means of coupling **62,** the internal conduit **58** within valve pin **5** is in fluidic communication with conduit tubing **834** to the pin isolation valve **3** of

linear flow through injection valve **850.** Conduit tubing **66** from the face seal valve **10** is then fluidically coupled to the internal conduit **82** of pin isolation valve **78** by means of coupling **70.**

[0066] Similarly, isolation valve pin **6** penetrates through stationary member **802** at penetration **824** such that the valve pin **6** can move linearly up and down. The internal conduit **82** within pin isolation valve *78* is then in fluidic communication with the volume of space **812** within the stationary member **802** that is bordered by the interfacing surface **810.** The valve pin **6** is positioned to interface with open port **880** on the interfacing surface **810.** The open port **880** is in fluidic communication with the volume of space **812**.

[0067] To seal the pin isolation valves **5** and **6,** the stationary member **802** includes self-energized lip seals **820a** and **820b,** respectively. The lip seals are commercially available from Furon, Inc. of Hoosick Falls, New York.

[0068] During the injection phase, the internal conduit **82** within the pin isolation valve **6** is in fluidic communication also with internal conduit **876** within the movable member **804** and with an open port **874** on an opposite end of movable member **804.** Fitting **8** is inserted into open port **874** so that the internal conduit **96** within fitting **8** is in fluid communication with a sample loop **22.** The internal conduit **96** within the fitting **8** is in fluidic communication with the column by means of flexible conduit **318** that is coupled to the fitting **8** by coupling **314.**

[0069] During the load phase, the pin isolation valve **6** is positioned to interface with blank port **892** on the surface **810** of movable member **804.** Similarly, the pin isolation valve **5** is positioned to interface with blank port **888** on the surface **810** of movable member **804.** These actions effectively isolate flow from the high pressure pump to the linear flow through injection valve **850** and to the column in the same manner as discussed previously for the first embodiment.

[0070] A means for moving the moving member **804** laterally is provided such as, but not limited to, a linear motor **864** which is coupled to the moving member **804** enables the pins **5** and **6** to be shifted between the open ports **860** and **880** and the blank ports **888** and **892,** respectively.

[0071] The linear flow through injection valve **850** is analogous to the rotary injection valve **300.** The linear valve **850** comprises stationary member **802'** and a movable member **804'.** The two members **802'** and **804'** interface at surface **810'.** The movable member **804'** slides along the surface **810'** while the stationary member **802'** remains in place. In this configuration, pin isolation valve **3,** having an internal conduit **58'** and which receives the fluid flow transferred from the high pressure pump through flexible conduit **834,** penetrates the stationary member **802'** at port **822'.** The pin isolation valve **3** is coupled to conduit **834** by means of coupling **62'** and is movably disposed within the stationary member **802'** such that isolation valve pin **3** can move up and down and so that the internal conduit **58** of valve poin **3** is in fluidic communication with a first opening **860'** of a flow through internal conduit **890'** that passes through the movable member **804'** to second opening **880'.** Both the first opening **860'** and the second opening **882'** interface with a chamber or volume of space **812'** within the stationary member **802'** that is bordered by the interfacing surface **810'.** The stationary member **802'** and the movable member **804,** act to seal the chamber **812'.**

[0072] Isolation valve pin **4** is movably disposed within the stationary member **802'** in second opening **880'** such that isolation valve pin **4** is in fluidic communication with the second opening **880'** of the enclosed flow through channel **890'.** Isolation valve pin **4,** having an internal conduit **96** and which transfers the fluid flow from the high pressure pump **101** to the column **102** through flexible conduit **836,** penetrates the stationary member **802'** at port **824'** and is coupled to flexible conduit **836** by means of coupling **854'.** The flexible conduit **836** is coupled to the isolation valve pin **6** of linear isolation valve **800** by means of coupling **70.**

[0073] Flexible conduit **852'** is fluidically coupled to needle **12** to fluidically couple with the internal conduit **812'** of isolation valve pin **1** which is movably disposed within the stationary member **802'** such that isolation valve pin **1** can move up and down and so that the internal conduit **812'** of valve pin **1** is in fluidic communication with a first opening **892'** of an enclosed flow through channel **886'** that passes through the movable member **804'** to fluidically couple to the sample loop **22** through flexible conduit **834'.**

[0074] Syringe **32** is fluidically coupled to flexible conduit **856'** which in turn fluidically couples with the internal conduit **858'** of isolation valve pin **2** which is movably disposed within the stationary member **802'** such that isolation valve pin **2** can move up and down and so that the internal conduit **858'** of valve pin **2** is in fluidic communication with a first opening **874'** of a flow through internal conduit **876'** that passes through the movable member **804'** to fluidically couple to the sample loop **22** through flexible conduit **836'.**

[0075] Open ports **894'** and **896'** in movable member **804'** serve as ends of flow through internal conduit **898'** so that when pin **1** and pin **2** are re-positioned to interface with open ports **894'** and **896',** respectively, the needle **12** and syringe **32** are then fluidically coupled directly to each other and disconnected from the sample loop **22.**

[0076] The stationary member **802'** is comprised of two surfaces **806a'** and **806b'** which surround the movable slider member **804'.** The two surfaces **806a'** and **806b'** each include self-energized lip seals **808a'** and **808b'**. The stationary member **802'** also forms an interfacing surface **810'** surrounding the movable member **804'.**

[0077] To seal the isolation valve pins **1, 2, 3** and **4,** the stationary member **802'** includes self-energized lip seals **820a'** and **820b',** respectively.

[0078] A means for moving the moving member **804'** laterally is provided such as, but not limited to, a linear motor **864'** which is coupled to the moving chamber **804'** enables the pins **1** and **2** to be shifted between the open ports **892'** and **874'**, and the open ports **894'** and **896'**, respectively. The linear motor **864'** can be driven by any means known in the art such as by electrical, hydraulic or pneumatic power.

[0079] During the load phase, the isolation valve poin **3** is positioned to interface with opening **860'** on the surface **810'** of movable member **804'**. Similarly, the isolation valve pin **4** is positioned to interface with opening **880'** also on the surface **810'** of movable member **804'**. These actions effectively isolate flow from the high pressure pump **101** to the sample loop **22** since the flow from the pump **101** is now recirculated from valve pin **3** through internal conduit **890'** to the column **102** through isolation valve pin **4**.

[0080] The needle **12** is then fluidically coupled to the sample loop **22** by means of the internal conduit **812'** of isolation valve pin **1** being fluidically coupled to the opening **894'** of internal conduit **898'**. Correspondingly, the syringe **32** is fluidically coupled to the sample loop **22** by means of the internal conduit **898'** being fluidically coupled to opening **896'** of internal conduit **876'**. The syringe **32** is then used to aspirate the sample fluid into the sample loop **22** from the needle **12.**

[0081] During the transition phase, the moving member **804'** is shifted laterally so that isolation valve pin **1** interfaces with opening **894'** and isolation valve pin **2** interfaces with opening **896'**, thereby isolating flow from the needle **12** to the syringe **32.** Correspondingly, the internal conduit **58'** of isolation valve pin **3** interfaces with opening **892'** of internal conduit **886'**. Internal conduit **96'** of isolation valve pin **4** interfaces with opening **874'** of internal conduit **876'.**

[0082] During the injection phase, as a result of the shifting of the moving member **804'** during the transition phase, flow from the pump **101** through isolation

valve **800** is then channeled through the sample loop **22** and on to the column **102** through the isolation valve **800.**

[0083] Another variation of the second embodiment is to design the stationary member **802** and the moving member **804** as a duplex or mirror-image design so that the moving member **804** further comprises ports and internal conduits for the pump and column, or a second pump and column, to be capable of serving a second face seal valve simultaneously.

[0084] Although described with respect to application to high pressure fluids, the various embodiments of the present invention can be applied to fluids at any operating pressure, including sub-atmospheric, i.e., vacuum applications as well.

[0085] The invention has been described herein with reference to particular exemplary embodiments. Certain alterations and modifications may be apparent to those skilled in the art, without departing from the scope of the invention. The exemplary embodiments are meant to be illustrative, not limiting of the scope of the invention, which is defined by the appended claims.